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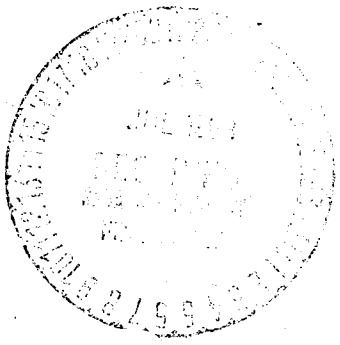

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NOISE REDUCTION IN AREAS OF Tu-124 AIRCRAFT TAKEOFF

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ABSTRACT. Suggestions for noise reduction in residential areas close to landing strips used by Tu-124 aircraft. The results of acoustic studies determining Tu-124 takeoff trajectories are discussed. Theoretical considerations and technical directions are given for noise-reducing piloting techniques. A family of reduced-noise takeoff and landing trajectories is defined as a function of the aircraft weight, engine power and flap rotation angle. This piloting technique ensures acceptable daytime and nighttime noise levels at distances of 4 and 7.5 km., respectively, from the starting point of the takeoff run.

Extensive use of the Tu-124 aircraft on comparatively short landing-takeoff strips (LTS) located close to population centers, makes the problem of noise reduction a primary one, particularly during takeoff. /157*

Under the conditions of the present intensity of operation, the acceptable noise level in populated areas located in the vicinity of foreign airports has been established at 110-112 PN db. of audible noise during the daylight hours, and 102 PN db. at night. The distances at which noise restrictions go into effect depend on the location of the populated areas along the directions of takeoff and landing, as well as on the sides of the LTS of a particular airport. Usually dealt with are distances of 1.5-3.0 km from the ends of the LTS's and 600-800 m and more on each side of the LTS axis.

One of the effective methods of noise reduction in a locality is the use of special techniques of piloting the airplane during the initial climb. This noise-reduction principle is based on increasing the distance from the noise source by initial climb at steeper trajectories, by turning the plane away from the populated areas and by decreasing the workload of the engines during flight over residential areas. Flight with takeoff acceleration of about (1.15 - 1.2) V-takeoff, constantly maintaining this speed in the subsequent climb,

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* Numbers in the margin indicate pagination in foreign text.

provides approximately two times greater angles of initial climb which, other things being equal, makes it possible to reduce the noise level by approximately 6 db. When such a method of takeoff is used, a redistribution of the balance of the available thrust occurs; its main part is used to attain the vertical speed V_y. During the usual takeoff with a takeoff run, carried out in accordance with the present Manual of Flight Operations and Aircraft Piloting, a thrust approximately equal to that of one engine is used to accelerate the aircraft, and the same amount of thrust is used to overcome head resistance, and only a small part of it (of the order of 0.1 of the thrust of one engine) is used to attain V_y.

Determination of piloting technique was conducted on the basis of 30 takeoffs under high, normal, and low-temperature conditions with a maximum takeoff weight, or one close to it. To obtain the limit trajectories and evaluation of the maximum angles of pitch, several flights with minimum takeoff weight were carried out.

To obtain trajectory data during takeoffs of the plane, /158 besides the regular panel instruments, special control equipment was used, which included a B-11 barograph and an SS-76 speedograph; changes in angle of pitch were also recorded on a K-2-21 oscillograph. The moment of takeoff during the takeoff run start was determined by means of an SP-11 overload recorder.

With Bruel and Kyer acoustical apparatus (noisemeters of the 2203 type, a microphone amplifier of the 2603 type, a capacitor microphone of the 4111 type), the noise in the locality was checked during takeoffs and flights of the aircraft. The acoustical investigations were conducted simultaneously with the determination of the "low noise" takeoff technique, and included determination of the change in the general noise level, its maximal value, and the frequency composition of the maximal noise. The noise spectrum was determined after decoding of the magnetic recording ("Comet" tape-recorder) under laboratory conditions.

The takeoffs made with different actual airplane weights and under different meteorological conditions (significant influence is exerted most of all by the temperature and the wind at ground level) correspond to different adjusted weights G_{adj}, which can be determined by means of the graph (Figure 1).

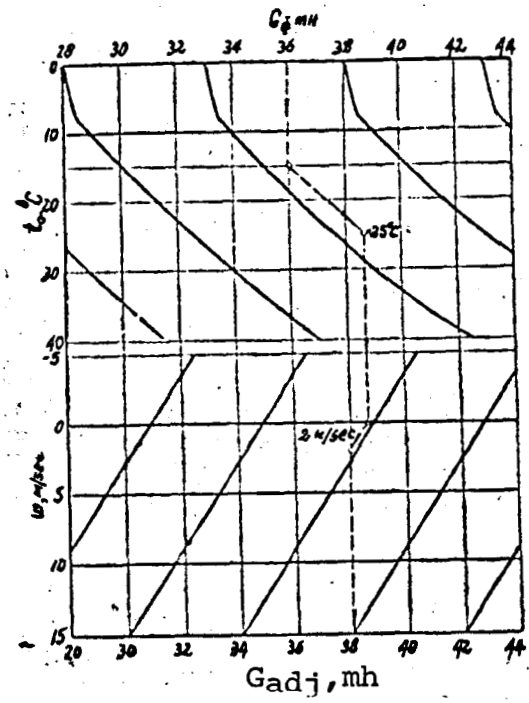

Fig.1-Determination of a derived weight of the Tu-124 aircraft.

The broken line shows the adjusted weight G_{adj} during plane takeoff with an actual weight $G\phi$ = 36 tons when the temperature at ground level is t_o = +25°C and the head-wind is w=2m/sec. With standard atmospheric conditions and in a calm, $G_{adj} = G\phi$. The graph of Figure 1 was obtained by computation.

The adjusted weight is the main parameter which determines the trajectory of the initial climb for a given piloting technique. As a result of averaging and generalizing actual takeoff trajectories, a family of average takeoff trajectories for different adjusted weights of the plane was obtained. These trajectories are shown in Figure 2 (here, L is the distance from the beginning of the run in km). They are valid for cases of takeoff and initial climb when the flaps are tilted 10°, under maximum engine work conditions.

After a short takeoff run, the flight is conducted at a constant speed, equal to V_2 + 30 km/hour, where V_2 is the safe speed of the initial climb, which depends on the aerodynamic characteristics of the plane and its flight weight. Nevertheless, to simplify the piloting and to decrease the angles of pitch, the takeoff runs are carried out without regard to flight weight up to the same speed, V_2 + 30 km/hour, /159 where V_2 is chosen for the maximum weight, i.e., the speed reserves vary, depending on the flight weight.

As a result, the trajectories of the initial climb during takeoff with a weight less than the maximum are somewhat more gradual than could have been attained. There the noise values remain practically unchanged.

The maximum noise levels L_{max}, as related to the altitude /160 of the flight and the engine work rate, obtained as a result of averaging the experimental data, are given in Figure 3. The levels in PN db. (broken lines in Figure 3) were obtained by computations based on averaged experimental spectra of the flight noise.

[1] K.D. Kryter, K.S. Pearsons, Some effects of spectral content and duration on perceived noise level. J.Acoust.Soc. America,1963, 35,866-886, (and also NASA TN D-1873-1963).

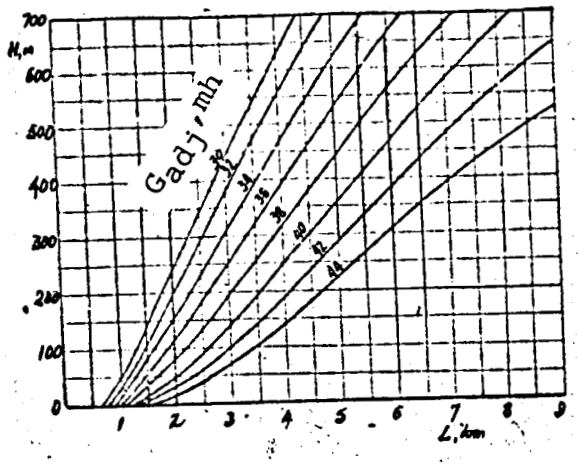

Figure 2. Initial climb trajectories during takeoff of the Tu-124 aircraft for a differing adjusted weight.

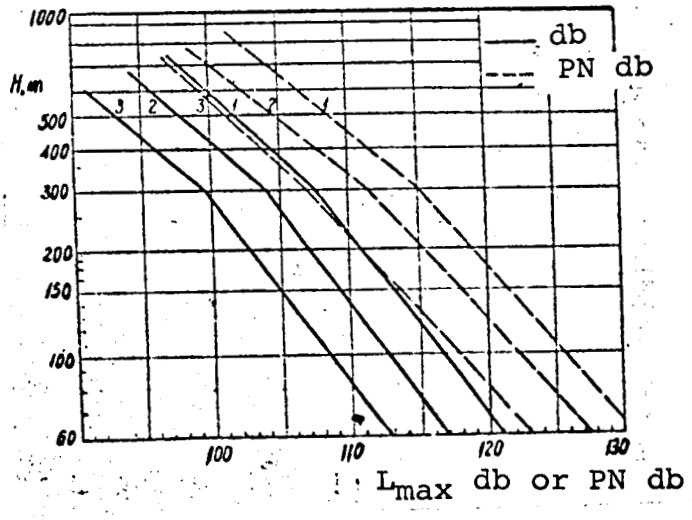

Figure 3. Noise created in an area during Tu-124 takeoff.
1 - maximum engine work conditions;
2 - normal rate;
3 - cruising rate.

Thus, for given conditions of takeoff (actual takeoff weight, meteorological conditions and proximity of populated areas to the starting point of the takeoff run), it is possible to determine the altitude of the plane flight above a populated area by means of the graphs given in Figures 1 and 2, and by means of Figure 3, it is possible to determine the maximum noise levels obtained with the engines working at maximum (n = 97%), nominal (n = 93%) or cruising (n = 88%) rates.

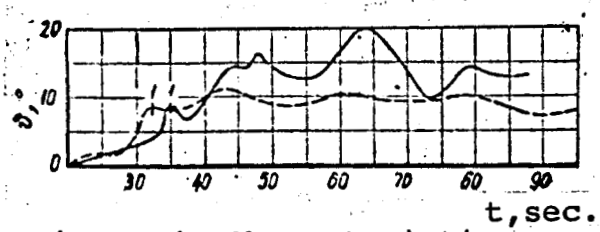

Figure 4. Characteristic change of the angle of pitch ϑ with respect to time during the takeoff of a Tu-124 aircraft with a weight of 38 tons, under conditions close to standard, according to the developed method (solid line) and according to the present Manual (broken line).
1 - moment of takeoff

As a rule, at an altitude of 300 m the work rate of the engines is decreased from maximum to nominal. But in certain cases, to maintain acceptable noise levels in populated areas situated very close by, or during night takeoffs, a decrease of the engine work rate to n = 86 - 88% is allowed after the completion of landing-gear retraction and at an altitude of not less than 150 m, with a gradual increase of the engine rate to nominal after the populated areas have been passed, or after an altitude of 500 m has been attained. Under high-temperature ground conditions (up to +30°C) and a maximum takeoff weight, when

the engines are converted to the rate of n=86 - 88%, the vertical speed is 2 -2.5 m/sec. Therefore such a rate can be used as a limit rate in noise reduction.

In all cases, flight is carried out at constant speed up to 500 m altitude, after which the flaps are retracted and the speed is increased to the most advantageous rate.

The piloting technique for the Tu-124 plane determined by this investigation, for the initial climb during takeoff made with maximum weight under standard atmospheric conditions, provides for acceptable night and day noise levels in the vicinity at distances, respectively, of 4 and 7.5 km from the starting point of the takeoff. When the engines are switched from the maximum rate to a rate n = 88% the indicated distances decrease respectively to 3 and 5.5 km. In practice, this means that 24-hour operation of the Tu-124 is possible /161 without violation of the existing noise restrictions.

A feature of the recommended piloting technique in the initial climb is an increased pitch angle of the order of 15 -16°, instead of the 10° angle associated with the existing method. A comparison of the pitch angle change during takeoff with a weight of 38 tons, under conditions close to standard, is given in Figure 4 (the solid curve is a takeoff made according to the determined method; the broken line is a takeoff made according to the existing manual).

The piloting technique in the initial climb, developed for the purpose of noise reduction, is recommended for normal as well as for complex meteorological conditions. It has now been included in the new Manual of Flight Operations and Aircraft Piloting for planes of the Tu-124 type.

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